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LA-UR 88-3919

CONF-881135

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LA-UR--88-3919

DE89 003586

TITLE: The MEGA Hardware Trigger System

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SUBMITTED TO: The Proceedings of the Rare Decay Symposium
Vancouver, B.C. Canada, November 29 - December 3, 1988

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

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THE MEGA HARDWARE TRIGGER SYSTEM

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ABSTRACT

The MEGA experiment is designed to search for the rare decay $\mu \rightarrow e \gamma$ with a branching ratio sensitivity of $\sim 10^{-13}$. As is typical of rare-decay experiments, extensive, online filtering of the data is required for MEGA. The MEGA experiment uses a hardware pattern-recognition system based on Programmable Array Logic (PAL) devices. Additional events are eliminated in an online ACP system before data are written to tape. The MEGA trigger system is generally applicable where high-rate, short-propagation-delay trigger systems are required. This report contains an introduction to the MEGA experiment, a discussion of the MEGA hardware trigger system and a discussion of the system's measured performance.

INTRODUCTION

The MEGA (Muon decays into an Electron and a GAmma ray) experiment is the search for the rare muon decay $\mu \rightarrow e \gamma$ at the Los Alamos Meson Physics Facility.[1] The experiment is designed with a branching-ratio sensitivity of $\sim 10^{-13}$, which represents a factor of 500 improvement over the existing limit.[2] The decay $\mu \rightarrow e \gamma$ violates conservation of lepton-family number, and the observation of this decay would signal new physics not explained by the minimal standard model.[3] Among the possible muon-number-violating rare decays, the branching ratio for $\mu \rightarrow e \gamma$ decay is relatively large in models employing more than three generations, right-handed neutrinos, extra Higgs doublets, composite particles, or supersymmetry. Because different decay modes are favored in different models, $\mu \rightarrow e \gamma$ is complementary to other muon-number-violating decays such as $\mu \rightarrow eee$, $\mu \rightarrow e\gamma\gamma$, $\mu A \rightarrow eA$, $K_L \rightarrow \mu e$ and $K^+ \rightarrow \pi^+ \mu e$. It is only through studying several different decay modes that the underlying physics can be understood.

THE MEGA DETECTOR

The signature for the decay $\mu \rightarrow e \gamma$ is purely kinematic and distinct from all prompt backgrounds; the positron and photon are back-to-back in time and have the fixed energy 52.8 MeV, which is one-half of the muon rest mass. The experiment is therefore designed to detect positrons and photons with energy near 50 MeV with good energy, spatial, and time resolutions.

A side view of the MEGA detector is shown in Fig. 1. The detector is contained within a superconducting solenoid with clear bore 2.2 m long by 1.9 m in diameter and 15 kG magnetic field. A positive muon beam of average intensity 3×10^7/sec is brought to rest in a CH_2 target that is located in the center of the detector. Each muon produces a positron via the normal muon decay $\mu \rightarrow e\nu\nu$, and the magnetic field confines these positron via the normal muon decay $\mu \rightarrow e\nu\nu$, and the magnetic field confines these positrons within a radius of 30 cm from the beam center. This inner region is instrumented with eight cylindrical multiwire proportional chambers (MWPC's) and two scintillator arrays and serves as the positron spectrometer. The positron spectrometer resolution is expected to be 0.6° in angle, 0.6% (FWHM) in energy and 0.5 nsec in time.

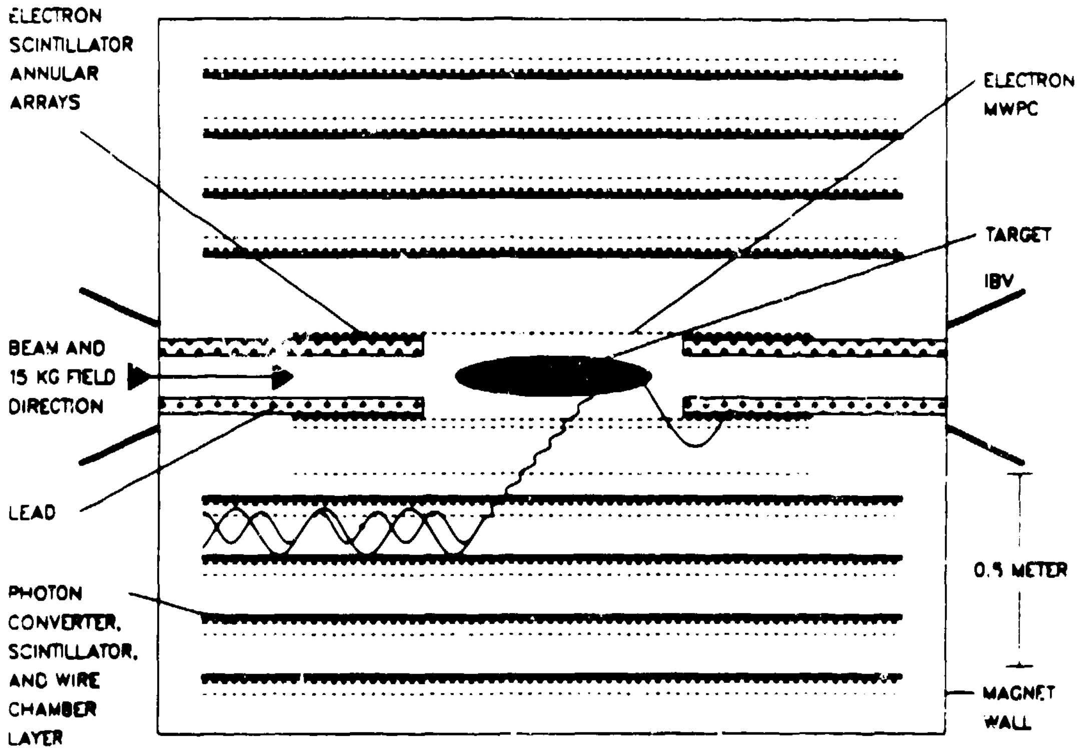

Figure 1. Side view of the MEGA detector.

Photons are detected in one of four independent, cylindrical pair spectrometers that surround the positron spectrometer. Photons are converted into $e^+ e^-$ pairs in one of two 0.025-cm thick lead converters located on the inner and outer radii of an MWPC. The MWPC determines which lead layer the photon converted in and is an essential part of the trigger signal. A barrel of 1 x 5 x 180 cm^3 scintillators is located just inside of the first lead layer for timing and trigger information. Outside of the second lead layer are three layers of drift chambers which provide tracking information to measure the pair energy. The photon spectrometer resolution is expected to be 10° in angle, 3% in energy, and 0.5 nsec in time.

THE HARDWARE TRIGGER SYSTEM

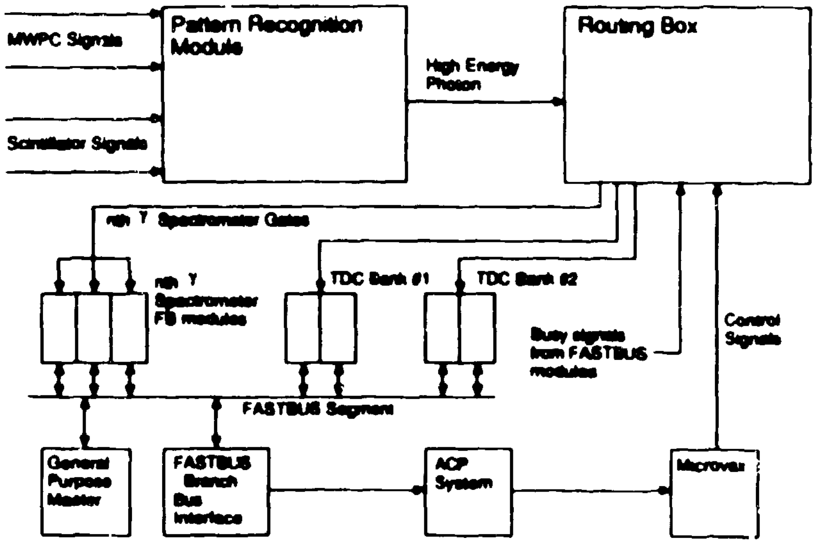

Figure 2. Schematic diagram of the MEGA trigger system.

Figure 2 contains a schematic drawing of the MEGA trigger system. A feature of this system is that to reduce deadtime all four photon spectrometers are read out independently and all scintillators in the positron spectrometer have two TDC channnels, which are read out on alternate events. The routing box performs the duties of sending trigger signals to the proper FASTBUS modules. The pattern recognition module translates photon shower widths into a photon energy cut. An online ACP (Fermilab's Advanced Computer Project)[4] system filters data by correlating positron tracks with photon spectrometer tracking information. The data are written to tape by a microVax computer.

Because of deadtime considerations, the trigger rate for each photon spectrometer must be limited to ~7 kHz. The integrated photon energy spectrum drops rapidly with energy, so a photon energy cut of ~42 MeV will reduce the trigger rate enough to meet the deadtime criterion.

The key to making a photon energy cut lies in the fact that the width of the $e^+ e^-$ shower produced by a converted photon is proportional to the momentum of the photon perpendicular to the beam direction. Thus, photons of energy 52.8 MeV will produce showers at least 16 cm wide. The MEGA hardware trigger uses pattern recognition modules to calculate the shower width and make a photon energy cut.

One pattern recognition module (PRM) has been built. This module is designed to implement an energy cut in the first photon spectrometer and is built with a combination of discrete ECL gates and ECL Programmable Array Logic (PAL) devices. The photon spectrometer contains 832 MWPC wires, that are OR'ed by eight into 104 MWPC signals, each representing a 2-cm wide section of the MWPC. Three of these MWPC section signals are required in coincidence, two separated by at least nine sections, inclusive, and a third section signal located somewhere between the first two. The logic also requires two scintillators in time and geometric coincidence with the MWPC section signals. The present PRM provides outputs corresponding to high and low photon energy thresholds in the upper or lower hemispheres of the spectrometer.

The PAL devices provide speed and flexibility. A different trigger pattern can be implemented with a new set of PALs with different programming. Presently, there are 104 PALs in the PRM. The entire trigger decision is made in 30 nsec, including receivers, drivers and wiring. There are plans to increase the integrated-circuit package density of the PRM with surface-mount devices, which will allow a single-board trigger module and a decrease in the trigger decision time of 5-10 nsec. A CAMAC-controlled tester module was built that sends random MWPC and scintillator hit patterns to the PRM and tests the output of the module. The tester module was very important for debugging the PRM, because of the large number of PALs and interconnections in the PRM.

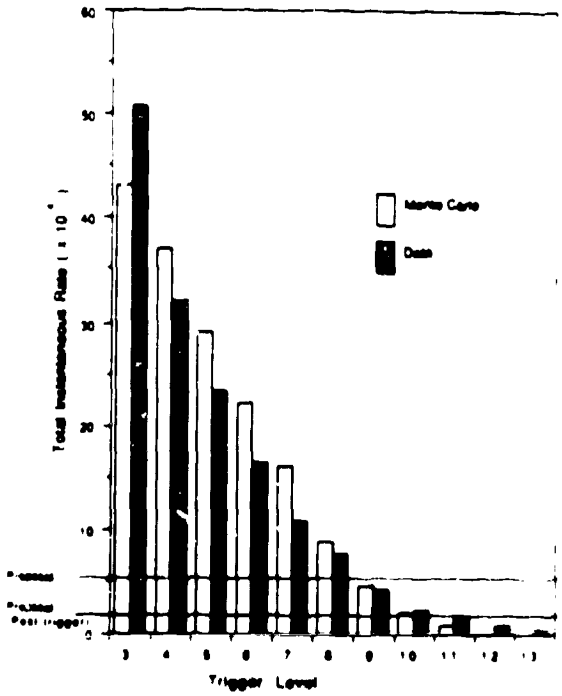

Figure 3. Comparison of Monte Carlo and measured shower-width distributions.

Figure 3 shows the measured shower width distribution spectrum compared to the Monte Carlo distribution, where the width is measured in units of 2-cm wide MWPC sections defined above. The significance of this figure is the fact that the Monte Carlo distribution matches the size and shape of the measured width distribution.

The other major component of the hardware trigger system is the routing box, which uses 10KH ECL logic to route trigger signals from the pattern recognition modules to the proper FASTBUS modules. The routing box keeps track of which photon spectrometer contained a shower, which TDC bank in the positron spectrometer is to be used, which triggers are selected in the control micoVAX and which FASTBUS modules are busy and cannot be triggered. The routing box has a propagation delay time of 12 nsec. To understand the timing of trigger signals from the routing box relative to signals from the detectors, we use project-management software which allows us to easily determine the critical timing paths and relative delays.

STATUS AND CONCLUSIONS

The MEGA collaboration plans on taking some $\mu \rightarrow e\,\gamma$ data in 1989. In 1990, we plan on having approximately 60% of the detector in place for data taking and in 1991 we plan on production data taking with the full detector. The trigger system will be built well within this schedule.

We have found in the MEGA collaboration a solution to the problem of complex pattern-recognition decisions that need to be made in short time periods. Our PAL-based trigger system offers both flexibility and high speed. Variations of this scheme are applicable to other experiments.

We wish to acknowledge the efforts of James Sena and Keith Stantz of Los Alamos in the development of this trigger system.

REFERENCES

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2. R.D. Bolton et al., Phys. Rev. D38, 2077(1988).
3. P. Herczeg, these proceedings and J.D. Vergados, Phys. Reports, 133, 96, (1986).
4. I. Gaines et al, IEEE Trans. on Nucl. Sci. NS-32, 1397 (1985).